U.S. Army Research Institute for
the Behavioral and Social Sciences

Research Report 1902

Initial Research on Multitask Training and Transfer: Research Issues for the Future Force

Peter S. Schaefer
Brian T. Crabb
U.S. Army Research Institute

June 2009

U.S. Army Research Institute
for the Behavioral and Social Sciences

A Directorate of the Department of the Army
Deputy Chief of Staff, G1

Authorized and approved for distribution:

BARBARA A. BLACK, Ph.D.
Research Program Manager
Training and Leader Development Division

MICHELLE SAMS, Ph.D.
Director

Technical review by

Jean L. Dyer, U.S. Army Research Institute
Carl W. Lickteig, U.S. Army Research Institute

NOTICES

REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) June 2009	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) January 2007 - September 2007

4. TITLE AND SUBTITLE Initial Research on Multitask Training and Transfer: Research Issues for the Future Force	5a. CONTRACT OR GRANT NUMBER 5b. PROGRAM ELEMENT NUMBER 622785
6. AUTHOR(S) Peter S. Schaefer and Brian T. Crabb (U. A. Army Research Institute)	5c. PROJECT NUMBER A790 5d. TASK NUMBER 275 5e. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 121 Morande Street Fort Knox, KY 40121-4141	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences 2511 Jefferson Davis Highway Arlington, VA 22202-3926	10. MONITOR ACRONYM ARI .. MONITOR REPORT NUMBER esearch Report 1902

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Subject Matter POC: Peter S. Schaefer

14. ABSTRACT *(Maximum 200 words)*:

New technologies currently under development will provide Soldiers with unprecedented amounts of information. However, these technologies will also require Soldiers to multitask (MT) under demanding circumstances. In two experiments, Soldiers were trained to complete single tasks (ST) or to MT. Their ability to multitask trained and novel tasks was then measured. Results indicate that although performance during training is superior for the ST trained participants, this pattern reverses when participants are required to MT both trained and novel tasks. Further, MT training performance is a better predictor of MT performance on both trained and novel tasks than ST training performance. Finally, working memory appears to be a relevant predictor only for individuals who have not received MT training. Future research issues should include an examination of task characteristics which may impact the transfer of multitasking skills. Implications for multitask training and personnel selection are discussed.

15. SUBJECT TERMS
Multitasking, Multitask Training, Prediction of Multitask Performance, Transfer of Training, Working Memory

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON
16. REPORT	17. ABSTRACT	18. THIS PAGE			Ellen Kinzer Technical Publication Specialist 703-602-8047
Unclassified	Unclassified	Unclassified	Unlimited	33	

Research Report 1902

Initial Research on Multitask Training and Transfer: Research Issues for the Future Force

Peter S. Schaefer
Brian T. Crabb
U.S. Army Research Institute

ARI – Ft. Knox Research Unit
James Lussier, Chief

U.S. Army Research Institute for the Behavioral and Social Sciences
2511 Jefferson Davis Highway, Arlington, Virginia 22202-3926

June 2009

Army Project Number 622785A790 | **Personnel, Performance and Training Technology**

INITIAL RESEARCH ON MULTITASK TRAINING AND TRANSFER: RESEARCH ISSUES FOR THE FUTURE FORCE

EXECUTIVE SUMMARY

Research Requirement:

As the United States Army transforms itself from the Current Force to highly networked Future Force, the duties of the Soldier (defined to include any person serving in the Army, not just enlisted personnel and noncommissioned officers) will likely become more and more demanding. The Army acknowledges this by referring to this future Soldier as a “multi-skilled Soldier” who will be with equipped a computer-integrated system of systems. Even in the Current Force, examples of multitasking abound. Consider a Soldier handling radio traffic while piloting an Unmanned Aircraft System (UAS), or listening to incoming messages while populating the Common Operational Picture (COP) on a battle command system such as Force XXI Battle Command, Brigade and Below ($FBCB^2$). Today’s Soldiers often handle simultaneous demands to perform digital and non-digital tasks. However, the future Soldier will be required to multitask even more, particularly on computer-based tasks. To better ensure Soldiers can handle these demands and more fully exploit new capabilities, multitask training and personnel selection may be essential.

Procedure:

In two experiments, Soldiers were trained to complete isolated tasks, called single task (ST) training, or a combination of tasks, called multitask (MT) training. Working memory of the participants was measured in Experiment 2. The ability of both the single task and multitask trained participants to multitask trained and novel tasks was then measured. The goals of the experiments were to replicate basic laboratory findings related to the training of multitasking ability, examine the role that working memory plays in training and test performance, and demonstrate (if possible) positive transfer of training to a multitasking scenario that included a novel task. In Experiment 1, the multitasking performance of MT-trained Soldiers was compared to that of ST-trained Soldiers. The ability of all participants to multitask when learning a novel subtask was also measured. In Experiment 2, the findings from Experiment 1 were replicated with a different Soldier population, and scores from a measure of working memory (WM) were collected.

Findings:

Both experiments demonstrated that although the training performance of ST-trained Soldiers was superior to that of MT-trained Soldiers, this pattern changed when all participants were required to multitask. This indicates that multitasking ability is more than just the ability to complete the constituent tasks in isolation. Furthermore the training scores for the MT-trained were predictive of multitasking performance for both trained and novel tasks, while the training scores for the ST-trained Soldiers were not. However, the correlations between multitasking performance and working memory exhibited the opposite pattern. Working memory predicted

multitasking performance for ST-trained Soldiers only. This suggests that appropriate training can sometimes minimize the impact of individual differences upon multitask performance.

Utilization and Dissemination of Findings:

The experiments described provide evidence that MT training improves later performance. This leads us to conclude that further research into multitask training could yield large benefits for the U.S. Army. If MT training is shown to have consistent, positive effects on the performance of Soldiers, we would strongly recommend the implementation of MT in institutional and unit settings. The MT training may improve the effectiveness and efficiency of Army training and equip Soldiers with the requisite skills for performing effectively in current and future operating environments.

INITIAL RESEARCH ON MULTITASK TRAINING AND TRANSFER: RESEARCH ISSUES FOR THE FUTURE FORCE

CONTENTS

List of Tables

List of Figures

INITIAL RESEARCH ON MULTITASK TRAINING AND TRANSFER: RESEARCH ISSUES FOR THE FUTURE FORCE

Introduction

Multitasking has been defined as the completion of any task "composed of two or more…relatively independent component tasks that are to be performed virtually concurrently" (Šverko, Jerneic, & Kulenovic, 1983). The ability to multitask is thus not the same as being able to complete different tasks in the absence of time pressure. Rather, it is the ability to quickly and accurately complete diverse tasks within an extremely narrow time frame. Multitasking is, of course, already required of Current Force Soldiers. Consider the following examples: (1) a Soldier handling radio traffic while piloting an Unmanned Aircraft System (UAS) (2) a Soldier listening to incoming messages while populating the Common Operational Picture (COP) on a battle command system such as Force XXI Battle Command, Brigade and Below ($FBCB^2$) (3) a Soldier engaged in a firefight and responding to priority information requests over the radio from his superiors. Obviously, successful performance in these situations is not easy. However, pending changes in technology will increase the multitasking demands placed upon the U.S. Soldier. These increased demands result from the transformation of the U.S. Army from the Current Force to the Future Force.

A central characteristic of the Future Force is the suite of computer-based, network-centric technologies. The goal is to provide Soldiers with unprecedented amounts of information via an array of sensing devises and improved communication systems. However, managing this information effectively will require Soldiers able to multitask quickly and accurately (Lickteig, Sanders, Durlach, Lussier, & Carnahan, 2003). Consider the role of robotic systems, for example. Soldiers must be capable of employing these systems, quickly absorbing the information sent back by these systems, keeping in mind the limitations of the robotic rule set—all the while changing tactics as need be, monitoring a COP, and keeping relevant personnel in-the-loop.

Research indicates that poor multitasking performance is at least partially responsible for the high attrition rates in air traffic control and 911 operator training programs (Sells, Dailey, & Pickrel, 1984, as cited in Joslyn & Hunt, 1998; Šverko, Jerneic, & Kulenovic, 1983). While these are high profile and high pressure multitasking jobs, more common examples exist (e.g., using a cell phone while driving, Weiss, 2007; typing an email while talking on the phone, Laff, 2007). It also appears that where multitasking is concerned, 'the whole is more than the sum of its parts.' That is, even if an individual can complete constituent tasks in isolation quickly and accurately (e.g., just driving or just talking on a cell phone), it does not follow that they can do both simultaneously without performance decrement. When participants have been trained to asymptote on single task performance, their multitasking performance still continues to improve across many trials (Schneider & Fisk, 1982). Similarly, other researchers found that when multitask performance was regressed onto single task performance, the residual variance was substantial (Ben-Shakhar & Sheffer, 2001). In other words, a large portion of multitasking performance was left unexplained by single task performance.

In sum, it appears that multitasking performance is a phenomenon in its own right. Although, the nature of multitasking performance is not well understood, several questions regarding its origin can be posed. First, is multitasking ability domain-general or domain-specific? Second, is the ability to multitask rooted in individual differences, experience (i.e., training), or some combination of the two? Third, even if multitasking can be trained, would performance gains transfer to new tasks and task combinations?

With regards to the first question, the evidence indicates that multitasking ability is not confined to specific domains. Two lines of evidence support this conclusion. First, factor-analytic studies have demonstrated common factor variance across domains (Šverko, Jerneic, & Kulenovic, 1983; Brookings, 1990). Furthermore, attempts to develop multitasking test batteries have demonstrated stable and sizable correlations between performance on these batteries and diverse job criteria. For example, Joslyn and Hunt (1998) found impressive correlations between performance on an abstract decision making (ADM) task and realistic simulations of air traffic control and 911 traffic dispatcher tasks. The ADM is a computer game in which participants are scored on their ability to sort objects into bins as rapidly as possible. Which bins are appropriate for which objects is determined on the basis of the size, shape, and color of the objects. There are at least three possible explanations for these correlations. One is similarity of task content. However, Joslyn and Hunt convincingly argue that there are manifest differences between the content of the job simulations and the ADM. A second plausible explanation involves common methods variance. That is, because the job simulations and the ADM were all administered via computer and the common medium of computer administration may be responsible for the correlations. However, two observations counter this explanation. First, the size of the correlations exceeds that usually seen when methods variance alone is a factor. Secondly, and more importantly, ADM performance was correlated with performance in a job simulation which was *not* computer administered. The third explanation—the one preferred by the authors—is that these correlations exist because a domain-general ability is being tapped. Further support for this position can be adduced from correlations between performance on standardized multitask test battery and call-center performance (Braun, Hüttges, Timm, Wieland, & Willamowski, 2002, as cited in König, Bühner, M., & Mürling, 2006) as well as performance of Swedish navy captains (Rosmark, 2001, as cited in König, Bühner, & Mürling, 2006).

In considering the second question, it appears that both individual differences and experience/training contribute to multitasking performance. Several researchers have found that practice does improve multitasking performance (Bherer et. al., 2005; Kramer, Larish, & Strayer, 1995; Schneider & Fisk, 1982). Other researchers—noting that multitasking requires people to switch from one task to another while storing information related to a task not currently being completed—have focused upon the role of working memory (WM), as WM is the psychological construct responsible for such processes (Meyer & Kieras, 1997). Data indicate that the relationship between WM and multitasking performance remain fairly strong, even after a significant amount of multitask training (König, Bühner, & Mürling, 2006; Bühner, König, Pick, & Krumm, 2006). However, it must be stressed that the stable correlations observed between WM and multitasking performance do not mean that training can never modify relationships between individual differences and multitasking performance. For example, Ben-Shakhar and Sheffer (2001) investigated the joint role of general mental ability and practice on multitasking performance. Results indicated that general mental ability predicts multitasking performance

only in the beginning stages of training, a finding consistent with skill acquisition theory (Ackerman, 1988). The role of general mental ability in the context of multitasking is especially relevant to the current project, because there is some debate in the research literature over whether or not WM and general mental ability are the same construct (Kyllonen & Chrystal, 1990) or just highly correlated with one another, with estimates around .65 (Engle, Tuholski, Laughlin, & Conway, 1999**;** Süß, Oberauer, & Wittman, 2002; Ackerman, Beier, & Boyle, 2002; Conway, Cowan, & Bunting, 2002). In any case, it appears that both individual differences and training have a role to play in multitasking ability. The manner in which both contribute may be partly due to specific task demands, how training is conducted, and which individual difference is being measured.

Finally, there is also evidence that performance gains in multitasking can transfer to new tasks and task combinations. Transfer of training can be defined as the degree to which trainees effectively apply the skills, knowledge, and/or attitudes gained in a training context to a new context (Baldwin & Ford, 1988). Transfer occurs when an individual applies previously learned knowledge to solve a novel problem. *Near transfer* where prior knowledge is used to solve a problem that is highly similar to the training problem(s), and *far transfer* where prior knowledge is used to solve a problem that is highly dissimilar to the training problem(s) (Gick & Holyoak, 1987; see Shadrick, Crabb, Lussier, & Burke, 2007 for more discussion of transfer in military training). Kramer, Larish, and Strayer (1995) randomly assigned participants to one of two training conditions. The training condition which improved performance on the multitasking performance of one set of tasks also improved multitasking performance on a transfer pair of tasks. Bherer et al., (2005) replicated this pattern with a different set of stimuli, and also found that the performance gains—on both the original and transfer tasks—remained one month later.

Taken as a whole, the evidence suggests that (a) multitasking requires more than just being able to perform single tasks in isolation (b) that multitasking ability on one set of stimuli can be used to predict multitasking performance on a different set of stimuli (c) that both training and individual differences (e.g., WM) play a role in multitasking performance, and (d) that performance gains in multitasking can generalize to new situations and remain somewhat stable. This line of reasoning suggests that the Army might want to investigate the potential of multitask training. Further, if selection of personnel based upon relevant individual differences is not an option, then the relationship between individual differences and training performance should at least be measured and understood. Such information might be used as a guide to how well a person would perform without multitask training, or how much multitask training would be required to reach some desired criterion. The research reported here investigates the potential benefit of multitask training in a military setting**.**

Experiment Overview

The first experiment was intended to replicate a basic finding from laboratory research, namely that multitasking performance requires more than just the ability to complete the constituent parts in isolation. Drawbacks to typical laboratory research are that the participant samples may not be representative of Soldiers, and the tasks used are not 'military-like' in nature. Therefore, we designed three relatively simple tasks with apparent face validity as military tasks. Soldiers were assigned to either a ST condition or a MT training condition. Both

groups were trained to perform the same two tasks, but the ST group was trained on one task at a time. The MT group was trained to perform both tasks simultaneously. To allow for comparison of performance across the training conditions, we intended to provide the ST group with twice as many training trials as the MT group. This was necessary, because otherwise the ST group would have half as much experience with any given stimulus as the MT training group. Although we succeeded in ensuring that the ST group completed a greater total number of training trials than the MT group, a coding error prevented the total number of training trials for the ST group from being twice that of the MT group.

After training, the ability of both groups to complete the trained tasks simultaneously was then measured which the authors consider a ‘direct test’ of learning on the same tasks. Both groups then completed another multitasking test in which one of the trained tasks was replaced with a novel task which the authors consider a ‘near transfer’ test of learning. In this ‘near transfer’ test all of the Soldiers were initially trained to complete an auditory task and a visual task and also required to complete an auditory task and visual task in the transfer condition. In addition, the auditory task used in the direct test was the same auditory task used in the near transfer test. We examine both the speed in terms of reaction time (RT) and accuracy of responses in terms of error rate (ER) which was defined as # errors / # total responses. All RTs are reported in milliseconds. The second experiment was an attempt to correct the coding error and to replicate the basic findings with different participants. The same basic procedures and stimuli were used, with the exception of number of trials per block for the ST group and the addition of a WM measure, described more fully later. The goal of this addition was to examine the interaction between training and individual differences.

Experiment 1

The goal of the first experiment was to replicate basic MT research findings using Soldiers and tasks that were more military-like in nature. Several questions guided the design of the experiment. First, would MT-trained individuals—even if given fewer training trials—outperform ST-trained individuals on the direct test? Second, would the MT-trained individuals outperform the ST-trained individuals during the near transfer test? Third, would the association between training performance and direct test/near transfer performance be stronger for MT-trained participants than for ST-trained participants?

Method

Participants

The participant sample (total n = 23) consisted of all males. Participant ages ranged from 23 to 42 years (M = 29.78 yrs, SD = 4.99). The amount of military experience ranged from 1 to 19 years (M = 8.57 yrs, SD = 4.38). Reported military occupational specialties included Infantry (n = 5), Cavalry Scout (n = 10), M-1 Crew (n = 2), Signal Support System Specialist (n = 1), and Chemical Operations Specialist (n = 1). All 19 participants who reported their rank were noncommisioned officers (NCOs) including 14 staff sergeants; the remaining participants did not report their rank. Approximately equal numbers of participants served in each condition (ST training group n = 12, MT training group n = 11).

Instruments and Tasks

All tasks were presented on personal computers with 15 inch monitors using E-PRIME, a software suite designed for running experiments. Participants were run in groups ranging from 3 to 6 individuals. Participants were Soldiers from Ft. Knox, Ft. Benning, and Aberdeen Proving Ground. All trials (regardless of condition) began with the presentation of a fixation point centered on the computer screen for 500 milliseconds, followed by presentation of the task stimuli. All trials lasted a maximum of 500 milliseconds. If 500 milliseconds passed with no response, the next trial would begin. In the multitasking trials, all stimuli were presented simultaneously. Each trial was followed by immediate performance feedback. The feedback indicated: (1) whether the answer given was correct or incorrect, (2) RT for that trial, and (3) the cumulative percent correct for that task. Approximately halfway through each training trial block, participants were given an opportunity to rest their eyes before continuing the experiment. Adjacent response keys (‘A’ and ‘S’ for one task, ‘K’ and ‘L’ for the other) were chosen to minimize physical/motor errors. We wanted to primarily measure the cognitive constraints imposed by multitasking. It is cognitively simpler to complete tasks in the absence of competing physical demands. If we had stipulated, for example, the more distant response key pairs of ‘A’ and ‘K’ for one task and ‘S’ and ‘L’ for the other, number of errors would have increased as a result of key selection, not multitasking difficulties per se. Each trial was conducted via a sampling-without replacement procedure. If, for example, there were 150 total stimuli available for a given task, 150 random selections would take place until the stimulus pool was exhausted. Upon the 151st trial, each stimulus would become available and the procedure would repeat.

NATO Alphabet Task. The North Atlantic Treaty Organization (NATO) Alphabet Task was an auditory categorization task. Participants wore headphones and were instructed to press the ‘A’ key if the auditory stimulus belonged to the current NATO call sign system (e.g., Alpha through Zulu). If the auditory stimulus did not belong to the NATO call sign system (e.g., Adam, Zebra), they were to press the ‘S’ key. Most of the non-target auditory stimuli used as distractors were pulled from earlier versions of the United States Army and Navy call sign systems. There were a total of 78 stimuli composed of 26 targets and 56 distractors.

Unmanned Aircraft System (UAS) Task. The UAS Task was a visual detection task which required participants to scan still photographs taken from UAS feeds of thermal images depicting the infrared radiation emitted by objects. The goal was to detect whether or not hostile vehicles could be detected. If a hostile was detected, participants were instructed to push the ‘K’ key. However, if no hostile was seen, the correct response was the ‘L’ key. There were a total of 150 stimuli composed of 30 targets and 120 distractors.

Military Equipment Task. The Military Equipment Task was a visual categorization task. Participants scanned a series of photographs of military equipment and were to classify them as belonging to either U.S. or foreign military forces. If the equipment was American, participants were instructed to press the ‘K’ key. If the equipment was foreign, they were to push the ‘L’ key. There were a total of 88 stimuli composed of 22 targets and 66 distractors.

Design and Procedure

Soldiers were run in sessions of up to six at one time. Each session lasted for a total of 2.5 hours. To prevent distraction from other participants, all Soldiers heard the auditory (NATO Alphabet) task through a set of headphones. Prior to training, participants were randomly assigned to either the single task or multitask training conditions. Participants assigned to the ST training condition completed multiple trials of NATO Alphabet and UAS tasks, each presented in isolation (task presentation order was determined via the random assignment function in E-PRIME). Participants in the MT training condition completed training trials in which the NATO Alphabet and UAS tasks were presented simultaneously. To distinguish single task trial blocks from multitask trial blocks, a '+' sign is used in between task names to indicate multitask trials (Table 1). Following training, all participants completed a block of trials with the NATO Alphabet and UAS tasks presented simultaneously (direct test), followed by a block of trials in which the NATO Alphabet and Military Equipment tasks were presented simultaneously (near transfer test). We originally intended to provide 300 trials for the NATO Alphabet task to the single task group. However, a coding error prevented this. As a result, ST-trained participants received only 228 trials for the NATO Alphabet task.

Table 1

Research Design and Procedure for Experiment 1

	Condition	
Phase	ST	MT
Training	NATO (228 trials) UAS (300 trials)	NATO + UAS (300 trials)
Direct Test	NATO + UAS (150 trials)	NATO + UAS (150 trials)
Near Transfer	NATO + ME (176 trials)	NATO + ME (176 trials)

Note: NATO=NATO Alphabet Task UAS=UAS Task ME=Military Equipment Task

Analyses

To display trends across trials, we divided each variable into 10 trial blocks of equivalent size and plotted mean RTs per trial block. Each RT graph includes 95% confidence intervals to indicate when RTs reliably differ. Only those comparisons which yielded significant *F* values are plotted. We intended to plot ERs in a similar fashion, but there was insufficient ER variability across trial blocks. Therefore, we use overall ERs as the unit of analysis. To compare differences in error rates, we conducted multivariate analysis of variance *(MANOVA)*. For each section—that is, the training, direct test, and near transfer sections—we report the more pertinent descriptive statistics within tables and provide more detailed descriptive data in Appendix A.

Table 2

Trial blocks in Experiment 1

	Condition	
Phase	ST	MT
Training	NATO = 23 trials each UAS = 30 trials each	NATO + UAS = 30 trials each
Direct Test	NATO + UAS = 15 trials each	NATO + UAS = 15 trials each
Near Transfer	NATO + ME = 18 trials each	NATO + ME = 18 trials each

Note: NATO=NATO Alphabet Task UAS=UAS Task ME=Military Equipment Task

Results

Training Data

As shown in Figure 1, the MT training group took longer to complete the NATO Alphabet task. A similar pattern is displayed in Figure 2 for the UAS tasks. For both tasks, then, the ST training group was quicker than the MT training group. However, the ERs for the training conditions did not differ for either the NATO Alphabet (F (1, 21) = .25, p > .05) or the UAS (F (1, 21) = .11, p > .05) tasks. Descriptive statistics are listed in Table 3.

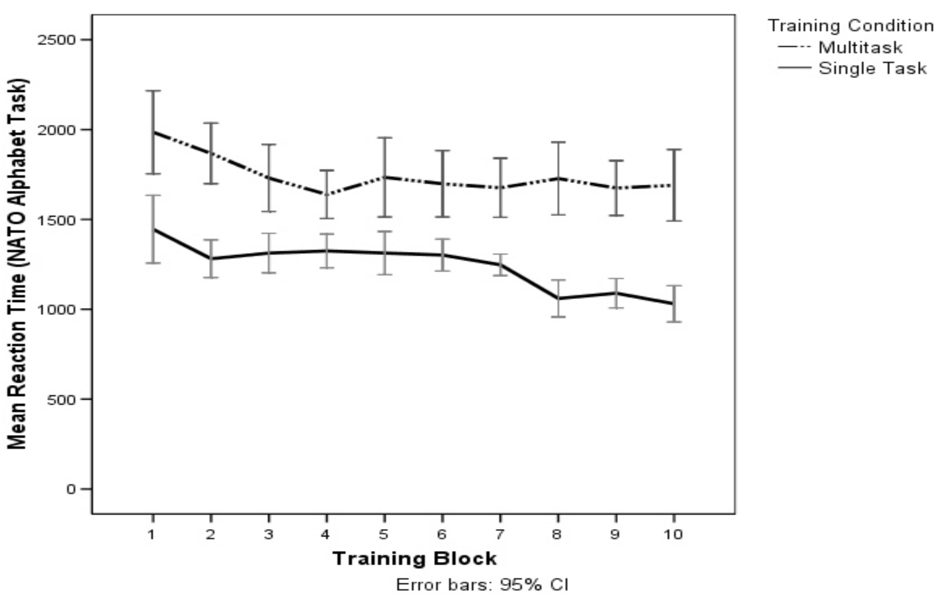

Figure 1. Training reaction times (m/sec) for NATO Alphabet Task, Experiment 1.

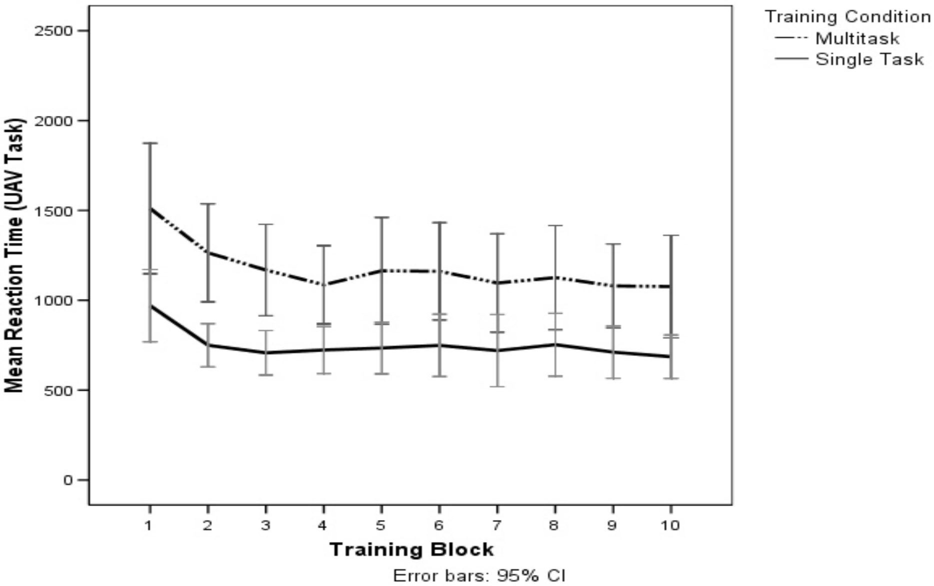

Figure 2. Training reaction times (m/sec) for UAS Task, Experiment 1.

Table 3

Means and standard deviations for Experiment 1 training data

	RT		Error	
Condition	Mean	SD	Mean	SD
Single				
NATO	1387	323	.06	.08
UAS	847	342	.05	.05
Multi				
NATO	1581	288	.05	.04
UAS	1067	374	.05	.03

Note: NATO=NATO Alphabet Task UAS=UAS Task

Direct Test

For both the NATO Alphabet task and the UAS task there were no reliable RT differences between the two training conditions. However, the MT training group had a non-significantly lower error rate in the NATO Alphabet task (F (1, 21) = 3.24, p = .08) and a significantly lower error rate in the UAS task (F (1, 21) = 7.37, p < .05).

Table 4

Means and standard deviations for Experiment 1 direct test data

	RT		Error	
Condition	Mean	SD	Mean	SD
Single				
NATO	1792	336	.03	.03
UAS	1262	374	.02	.02
Multi				
NATO	1704	203	.01	.01
UAS	1216	229	.01	.01

Note: NATO=NATO Alphabet Task UAS=UAS Task

Near Transfer Test

For both the NATO Alphabet task and the Military Equipment task there were no reliable RT differences between training conditions. Furthermore, the ERs for the training conditions did not differ significantly for either the NATO Alphabet (F (1, 21) = .42, $p > .05$) or the Military Equipment (F (1, 21) = .68, $p > .05$) tasks.

Table 5

Means and standard deviations for Experiment 1 near transfer data

	RT		Error	
Condition	Mean	SD	Mean	SD
Single				
NATO	1792	336	.02	.02
ME	1790	429	.07	.02
Multi				
NATO	1704	203	.03	.02
ME	1753	341	.08	.05

Note: NATO=NATO Alphabet Task ME=Military Equipment Task

Discussion

During training, the MT training group committed the same number of errors as the ST training group and exhibited reliably slower reaction times for both tasks. However, this pattern changed during the direct test of multitasking ability. In the direct test, the MT training group committed fewer errors than the ST group, and completed the tasks as quickly. During the near transfer test, neither the reaction times nor the error rates were different for the two groups.

This pattern of results suggests that multitask performance does require more than just being able to complete the constituent tasks. Despite more training trials—and superior training performance—the ST training group was outperformed by the MT training group during the direct test phase. This is a point of some importance, because if we had only the training data to observe, we might expect that the single task training group would do better during the direct test phase. Factors which optimize performance during training may not promote skill retention. Some research has found that variables which improve training performance may retard test performance, and vice versa (Schmidt & Bjork, 1992). However, the present results also suggest that multitasking training improvements may be largely limited to tasks which are highly similar to those trained.

A stronger argument for the superiority of MT training could be made if the ST participants had completed as many single trials per task as the MT group completed overall. This was, of course, our original intention. We therefore decided to correct the coding error and replicate Experiment 1 with different participants.

Experiment 2

There were two goals in this experiment. The first goal was to correct the coding error from Experiment 1 and see if the same pattern of results would obtain. The second goal was to assess the extent to which training data and individual differences uniquely predicted multitasking performance. The individual difference measured was that of WM. We chose to measure WM because previous research has found a relationship between WM and multitasking (König, Bühner, & Mürling, 2006; Bühner, König, Pick, & Krumm, 2006). The main approach taken to measuring WM in those studies (König, Bühner, & Mürling, 2006; Bühner, König, Pick, & Krumm, 2006) was to administer several different measures of WM to large samples of individuals and estimate their standing on the latent WM factor via factor analysis. This approach was untenable in the current context because of time and sample size limitations. Therefore, it was decided to pick a single measure of WM with established validity and reliability.

In the end, we chose the Operation Span (OSPAN) (Turner & Engle, 1989). Support for OSPAN validity comes from findings demonstrating its loading on a common WM factor along with other validated WM measures (Engle, Tuholski, Laughlin, & Conway, 1999). The OSPAN reliability (estimated at .88, Klein & Fiss, 1999) is excellent, and is in fact slightly higher than that of other common WM measures. An additional advantage to t he OSPAN test is the public availability of an automated EPRIME version (Heitz, Schrock, & Engle, 2005).

The basis of the OSPAN test is simple. Individuals are shown a letter, followed by a math problem which they are required to mentally solve. A possible answer to the problem is provided, and participants are required to indicate if the answer is correct or not. Then another letter is shown. This repeats for several iterations, at the end of which participants are required to select—in the correct order—from a multiple choice list the letters which were displayed. Participants must maintain an 85% correct answer rate for the math problems, in order to avoid an accuracy tradeoff between the math problems and word recall. Any trials on which a participants RT is greater than +/- 2SD their mean RT is discarded. The version of the OSPAN test used in this research was an automated version implemented in E-PRIME (Heitz, Schrock, & Engle, 2005).

Method

Participants

The participant sample (*n*=19) was composed of all males. Ages ranged from 20 to 38 years (*M* = 23.53, *SD* = 11.92, *n* reporting = 16). Years of military experience ranged from 1 to 17 years (*M* = 7.1, *SD* = 6.3, *n* reporting = 19). Military ranks included Private (*n* = 7), Specialist (*n* = 2), and Sergeant (total *n* = 9, 7 = staff sergeants, 2 not specifying). Reported military occupational specialties included mechanical maintenance (*n* = 17) and unit supply specialist (*n* = 2). Approximately equal numbers of participants served in each condition (ST training group *n* = 9, MT training group *n* = 10).

Instruments and Tasks

With the exception of the OSPAN test, the instruments and tasks used in Experiment 2 are the same as those used in Experiment 1.

Design & Procedure

The design and procedure replicated those used in Experiment 1, with the exception of the addition of the OSPAN procedure and the correction of the coding error which occurred in Experiment1. To minimize order effects, participants were randomly chosen to either complete the OSPAN procedure prior to or following training and testing.

Analyses

The analyses largely replicate those from Experiment 1. Again we plot reliably different RTs by training condition and training block. Because the coding error was corrected, however, there were 30 trials per block for the ST training group data in the NATO Alphabet task (see Table 6 below). Once again, the overall ER was too low to examine fruitfully on a per-trial block basis. Therefore, we again used the percent errors across all trials. (More detailed descriptives from these analyses can be found in Appendix B.) Because we also wished to assess how well OSPAN scores and training performance could predict multitasking performance, we computed a series of regression equations using OSPAN scores and training performance as predictors and multitasking performance measures as criterion variables.

Table 6

Trial blocks in Experiment 2

	Condition	
Phase	ST	MT
Training	NATO = 30 trials each UAS = 30 trials each	NATO + UAS = 30 trials each
Direct Test	NATO + UAS = 15 trials each	NATO + UAS = 15 trials each
Near Transfer	NATO + ME = 18 trials each	NATO + ME = 18 trials each

Note: NATO=NATO Alphabet Task UAS=UAS Task ME=Military Equipment Task

Results

Training Data

As shown in Figure 3, the MT training group took longer to complete the NATO Alphabet task. A similar pattern is displayed in Figure 4 for the UAS task. For both tasks, then, the MT training group was slower than the ST training group. There were no differences in ERs between the training conditions for either the NATO Alphabet (F (1, 17) = .70, p >.05) or the UAS (F (1, 17) = .44, p >.05) tasks.

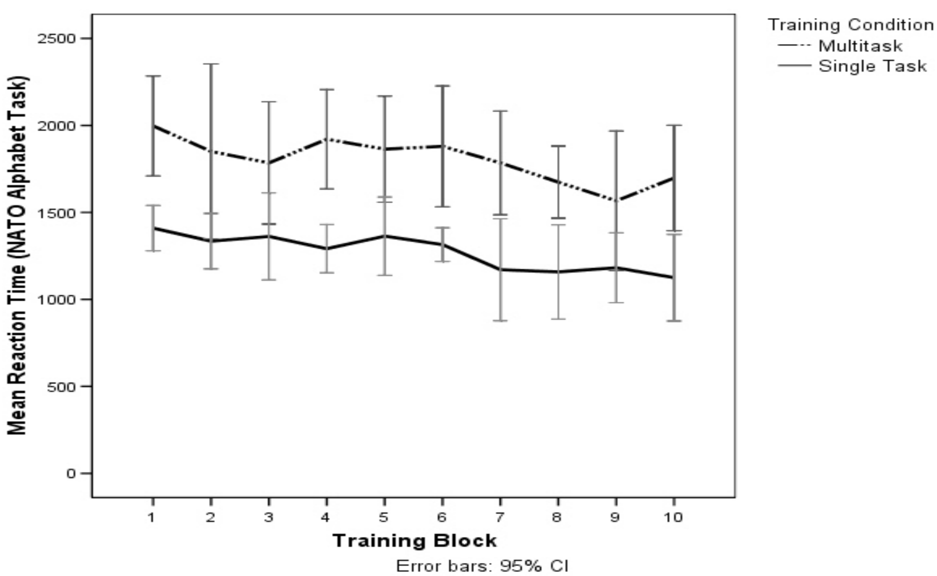

Figure 3. Training reaction times (m/sec) for NATO Alphabet Task, Experiment 2.

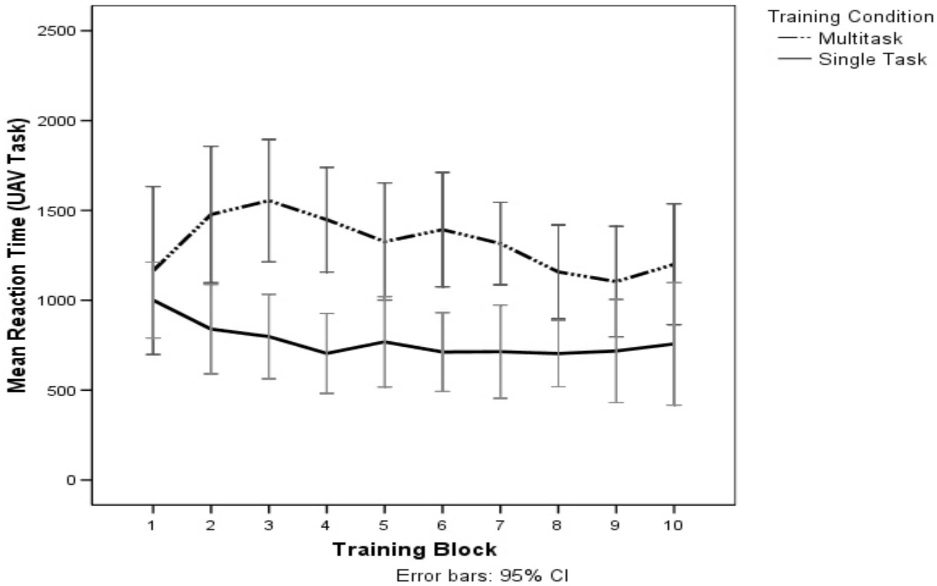

Figure 4. Training reaction times (m/sec) for UAS Task, Experiment 2.

Table 7

Means and standard deviations for Experiment 2 training data

	RT		Error	
Condition	Mean	SD	Mean	SD
Single				
NATO	1019	343	.12	.17
UAS	1263	374	.13	.19
Multi				
NATO	1788	287	.08	.06
UAS	1329	276	.08	.08

Note: NATO=NATO Alphabet Task UAS=UAS Task

Direct Test

There were no reliable RT differences between training groups for either the NATO Alphabet or UAS tasks. There were also no significant differences in ERs between training conditions in either the NATO Alphabet (F (1, 16) = 322, p >.05) or the UAS (F (1, 16) = 1.64, p >.05) tasks.

Table 8

Means and standard deviations for Experiment 2 direct test data

	RT		Error	
Condition	Mean	SD	Mean	SD
Single				
NATO	1795	323	.01	.01
UAS	1344	314	.01	.01
Multi				
NATO	1799	376	.05	.07
UAS	1343	400	.03	.05

Note: NATO=NATO Alphabet Task UAS=UAS Task

Near Transfer Test

There were no reliable RT differences between training groups for either the NATO Alphabet or Military Equipment tasks. There were also no significant differences in ERs between training conditions in either the NATO Alphabet (F (1, 16) = .36, p >.05) or the Military Equipment (F (1, 16) = .80, p >.05) tasks.

Table 9

Means and standard deviations for Experiment 2 near transfer data

	RT		Error	
Condition	Mean	SD	Mean	SD
Single				
NATO	2182	486	.09	.04
ME	1263	374	.03	.02
Multi				
NATO	2378	484	.08	.05
ME	1216	229	.05	.03

Note: NATO=NATO Alphabet Task ME=Military Equipment Task

Individual Differences and Training Performance as Predictors

To examine the unique predictive contribution of OSPAN scores to multitasking in Experiment 2, we computed a series of regression equations. We attempted to predict RTs in the direct test and near transfer phases using OSPAN scores and training RTs, and to predict ERs in the direct test and near transfer phases using the OSPAN scores and training ERs. We emphasize that the point of these regression equations was to examine the *unique* predictive role of OSPAN scores. Therefore, we report only the *r* values associated with the OSPAN scores.

When computing the regression equations, we decided to use backwards stepwise regressions. In such a procedure, all of the desired predictor variables are entered into an equation and any predictor which fails to significantly predict criterion variance—set by default in SPSS at *p* less than or equal to .10—is removed from the equation. We used this approach because we had no compelling a priori reason to enter the predictor variables in a particular sequence. Because the same predictors are used in more than one regression equation, the *p* values should be viewed with caution; however, this skepticism should be counterweighted by the fact that any significant *p* values were obtained with very small sample sizes. When computing these regression equations, summary variables were used as predictors and criterion. That is, for a given individual we use that person's OSPAN score, mean overall RTs, and mean overall ERs.

ST Training Group

Reaction Times. Four backwards stepwise regression equations were computed. The same three predictor variables were used in all four equations: OSPAN scores and training RTs (e.g., NATO Alphabet and UAS tasks). The criterion variables were the RTs in the direct test (NATO Alphabet and UAS tasks) and near transfer (NATO Alphabet and Military Equipment tasks) phases. The OSPAN scores uniquely predicted direct test RTs in both the NATO Alphabet ($r = .75$, $p < .05$) and the UAS ($r = .76$, $p < .05$) tasks. The OSPAN scores failed to predict RTs in the near transfer tasks.

Error Rates. A similar procedure was followed for predicting ERs by the ST training group. The predictor variables were the training phase ERs (in both the NATO Alphabet and UAS tasks) and OSPAN scores. The criterion variables were the direct test (NATO Alphabet and UAS tasks) ERs and near transfer (NATO Alphabet and Military Equipment) ERs. The OSPAN scores failed to uniquely predict ERs in any of the tasks.

MT Training Group

The regressions in this section proceeded in the same fashion as those described above—the same predictor and criterion variables were used. The OSPAN scores failed to uniquely predict RTs and ERs for any of the tasks.

Discussion

The findings of Experiment 2 are largely consistent with those from Experiment 1. When looking at the data across experiments, it is clear that during training ST participants tend to complete tasks more quickly and as accurately as MT participants. However, this speed advantage disappears when all participants are required to complete both of the trained tasks simultaneously. There is also some evidence that MT-trained participants commit fewer errors during multitasking than ST-trained participants. Until more difficult tasks are examined, however, this conclusion remains tentative.

As for the role of WM in multitasking, it appears to depend upon training condition. When individuals have not been trained to multitask, WM uniquely predicts RT variance—at least during the direct test phase. This does not hold true, however, for individuals who have been trained to multitask. Would we see a similar change in the role of training performance as a predictor as a function of training condition? To examine this question, we decided to focus upon the role of training performance as predictors of multitasking performance.

Using Training to Predict Multitasking Performance

Previous research has found that multitasking performance is not well explained by performance of the constituent tasks in isolation (Ben-Shakhar & Sheffer, 2001; Schneider & Fisk, 1982). When this observation is combined with the positive transfer of multitasking learning found by other researchers (Kramer, Larish, & Strayer, 1995; Bherer et al., 2005), it seemed plausible to predict that training performance for the MT trained participants would be a better predictor of direct test and near transfer phases than ST training performance.

To maximize statistical power, we wished to use the data from both experiments. However, given the coding error which occurred in Experiment 1, we had to ensure that the data patterns in Experiments 1 and 2 were not significantly different from one another. To examine this, we computed a set of interaction vectors consisting of predictor variables and a dummy variable indicating whether or not a data point was drawn from Experiment 1 or 2. We then regressed the criterion variables onto the relevant interaction vectors. Results indicated an absence of interaction effects, justifying combining data from the two experiments.

The regressions proceeded in an analogous fashion to those used before, with the exception that OSPAN scores were not included (and, indeed, not available for data from Experiment 1). Backwards stepwise procedures were once again used. For each regression equation two predictor variables were used (either training ERs or training RTs). Upon occasion, only one predictor was retained. Following convention (Jensen, 1980), we use r to indicate bivariate correlations and R to indicate multiple correlations.

ST Training Group

Reaction Times

Training RTs did predict NATO Alphabet RTs in the near transfer phase (R = .56, p <.05). However, for the remaining three criterion variables there were no significant regressions.

Error Rates

Training ERs failed to significantly predict ERs in any of the four criterion variables.

MT Training Group

The procedure for regressing MT training group direct test/near transfer performance onto training performance was the same as that used for the ST training group above. Precisely the same predictor and criterion variables were used.

Reaction Times

Training RTs did predict direct test RTs for both the NATO Alphabet task (r = .66, p < .05) and UAS (r = .68, p < .05). Training RTs also predicted near transfer RTs for the NATO Alphabet (r = .69, p < .01) and Military Equipment (r = .46) tasks.

Error Rates

Training ERs were highly predictive of direct test ERs for both the NATO Alphabet (R = .90, p < .05) and UAS (R = .89, p < .05) tasks. However, training ERs failed to predict near transfer errors in either the NATO Alphabet or Military Equipment tasks.

Discussion

The findings from the above analyses replicate and extend earlier research. The regression equations do indicate that multitasking performance is composed of more than simply being able to perform the constituent tasks in isolation. Single task ERs and RTs did not significantly predict those aspects of multitasking performance. In contrast, multitask ERs and RTs did a reasonable job of predicting subsequent multitask performance. Reaction times in particular appeared to be predictable across different task sets.

General Discussion

Experiments 1 and 2 demonstrate that the superior training performance of single tasks in isolation is, at best, misleading. When required to perform trained tasks simultaneously—that is, to multitask—single task trained participants lose their speed advantage and sometimes commit more errors than participants who were multitask trained participants. Furthermore, ERs and RTs derived from multitask training may serve as better predictors of later multitasking performance than measures derived from single task training. Given that the tasks used here had

very low ERs, we predict that using more difficult tasks should result in (1) greater differences in ERs between ST and MT-trained participants and (2) enhanced predictability of multitasking ERs from ERs during MT training.

In addition, when appropriate multitask training is given the impact of WM upon multitasking performance appears to be minimized. This is consistent with previous research (Ben-Shakhar & Sheffer, 2001) which found that another individual difference (general mental ability) was correlated with multitasking performance only in the early stages of training. When, therefore, multitask training is unavailable, it is worthwhile to assess the working memory of individuals before placing them in jobs which require efficient and effective multitasking.

While there is evidence supporting the use of MT training, there are a number of research questions that need investigation before useful recommendations can be made to the U.S. Army. The current research only looked at short-term effects of MT. Do the beneficial effects of MT training persist over time or does the difference fade as the ST training group gains more experience in a MT environment? The tasks used here required similar motor movements such as pressing keys on a computer screen. Tasks that physically interfere with each other—e.g., require different or even opposing body movements—may not be as predictable. The role of working memory also deserves further exploration. One study (Bühner, König, Pick, & Krumm, 2006) found that different aspects of working memory predict multitasking speed and accuracy. Further research into which working memory measures would predict different aspects of performance (speed, accuracy) in a military context would be a worthwhile undertaking. Depending upon task, MOS, and mission characteristics, one or the other aspect of performance may become more important.

Conclusions

Evidence from this set of experiments indicates that relying upon ST training performance as an indicator of MT performance is misleading. Given that fewer training trials were provided to the MT participants, we can plausibly argue that MT training is more efficient, effective, and predictive of later MT performance than is ST training. When considering the role that new technologies will play in the Future Force, it is evident that an ever increasing premium will be placed upon multitasking ability. This leads us to conclude that further research into multitask training could yield large benefits for the U.S. Army. If MT training is shown to have consistent, positive effects on the performance of Soldiers, we would strongly recommend the implementation of MT in institutional and unit settings. The MT training may improve the effectiveness and efficiency of Army training and equip Soldiers with the requisite skills for performing effectively in current and future operating environments.

References

Ackerman, P. L. (1988). Determinants of individual differences during skill acquisition: Cognitive abilities and information processing. *Journal of Experimental Psychology: General, 117*, 288-318.

Ackerman, P. L., Beier, M. E., & Boyle, M. D. (2002). Individual differences in working memory within a nomological network of cognitive and perceptual speed abilities. *Journal of Experimental Psychology: General, 131* (4), 567-589.

Baldwin, T., & Ford, J. (1988). Transfer of training: A review and directions for future research. *Personnel Psychology, 41,* 63-105.

Ben-Shakhar, G., & Sheffer, L. (2001). The relationship between the ability to divide attention and standard measures of general cognitive abilities. Intelligence, 29 (4), 293-306.

Bherer, L., Kramer, A. F., Peterson, M. S., Colcome, S., Erickson, K., & Becic, E. (2005). Training effects on dual-task performance: Are there age-related differences in plasticity of attentional control? *Psychology and Aging, 20* (4), 695-709.

Brookings, J. B. (1990). A confirmatory factor analytic study of time-sharing performance and cognitive abilities. *Intelligence, 14* (1), 43-59.

Braun, V., Hüttges, M., Timm, E., Wieland, R., & Willamowski, A. (2002). *Instrumente zurPersonalauswahl und Personalentwicklung im Call Center (CCall report 13)* [Instruments for personnel selection and development in call centres (CCall report 13)]. Hamburg, Germany: Verwaltungs-Berufsgenossenschaft.

Bühner, M, König, C., Pick, M., & Krumm, S. (2006). Working memory dimensions as differential predictors of the speed and error aspect of multitasking performance. *Human Performance, 19* (3), 253-275.

Conway, A. R. A., Cowan, N., & Bunting, M. F. (2002). A latent variable analysis of working memory capacity, short-term memory, processing speed, and general fluid intelligence. *Intelligence, 30* (2), 163-184.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128* (3), 309-331.

Gick, M., & Holyoak, K. (1987). The cognitive basis of knowledge transfer. In S. M. Cromier & J.D. Hagman (Eds.), *Transfer of Learning : Contemporary Research and Applications* (pp. 9-46). San Diego, CA: Academic Press Inc.

Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods,* 37 (3), 498-505.

Jensen, A. R. (1980). *Bias in mental testing*. New York: Free Press.

Joslyn, S., & Hunt, E. (1998). Evaluating individual differences in response to time-pressure situations. *Journal of Experimental Psychology: Applied, 4* (1), 16-43.

Klein, K., & Fiss, W. H. (1999). The reliability and stability of the Turner and Engle working memory task. *Behavior Research Methods, Instruments, and Computers, 31* (3), 429-432.

König, C. J., Bühner, M., & Mürling, G. (2006). Working memory, fluid intelligence, and attention are predictors of multitasking performance, but polychronicity and extraversion are not. *Human Performance, 18* (3), 243-266.

Kramer, A. F., Larish, J. F., & Strayer, D. L. (1995). Training for attentional control in dual task settings: A comparison of young and old adults. *Journal of Experimental Psychology: Applied, 1* (1), 50-76.

Kyllonen, P. C., & Chrystal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence, 14*, 389-433.

Laff, M. (2007). The myth of multitasking. *T & D, 61* (3), 20.

Lickteig, C. W., Sanders, W. R., Durlach, P. J., Lussier, J. W., & Carnahan, T. J. (2003). *Human performance essential to battle command: Report on four future combat systems command and control (FCS C2) experiments* (ARI Research Report 1812). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Meyer, D. E., & Kieras, D. E. (1997). A computational theory of executive cognitive processes and multiple-task performance: I. Basic mechanisms. *Psychological Review, 104,* 3–65.

Rosmark, B. (2001). *Validering av ett simultankapacitetstests prediktionsförmåga av framgång: utbildningen av båtchefer (stridsbåtförare)* [Validation of a simultaneous capacity test for the prediction of the training success of captains (combat boats)] (RKS Promemoria 2001–07–31). Stockholm, Sweden: Pliktverket Regionkontor Stockholm.

Schneider, W., & Fisk, D. (1982). Concurrent, automatic, and controlled visual search: Can processing occur without resource cost? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 261-278.

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3* (4), 207-217.

Sells, S. D., Dailey, J. T., & Pickrel, E. W. (Eds.). (1984). *Selection of air traffic controllers* (FAA-AM-84-2). Washington, DC: Federal Aviation Administration.

Shadrick, S. B., Crabb, B. T., Lussier, J. W., & Burke, T. J. (2007). *Positive transfer of adaptive battlefield thinking skills.* (ARI Research Report 1873). Arlington, VA: U.S. Army Research Institute for the Behavior and Social Sciences

Süß, H. M., Oberauer, K., & Wittman, W. W. (2002). Working-memory capacity explains reasoning ability-and a little bit more. *Intelligence, 30* (3), 261-288.

Šverko, B., Jerneic, Z., & Kulenovic, A. (1983). A contribution to the investigation of time-sharing ability. *Ergonomics, 26* (2), 151-160.

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory & Language, 28*, 127-154.

Weiss, M. (2007). Confronting driver distraction. *Futurist, 41* (1), 16-17.

Appendix A

Reaction Time Descriptive Statistics for Experiment 1

Training Data

DV	Training Condition	Training Block	*M*	*SD*
NA	MT	1	1985.13	343.533
		2	1867.39	250.593
		3	1730.41	277.219
		4	1639.02	198.736
		5	1734.04	327.498
		6	1698.35	274.384
		7	1676.27	244.477
		8	1727.54	300.877
		9	1674.86	227.024
		10	1690.39	296.013
	ST	1	1445.27	296.741
		2	1281.63	164.948
		3	1312.75	172.488
		4	1324.59	147.687
		5	1313.03	188.961
		6	1301.59	139.513
		7	1247.34	94.257
		8	1060.18	161.907
		9	1089.40	128.990
		10	1030.52	158.932
UAS	MT	1	1510.31	540.325
		2	1264.31	405.804
		3	1168.33	379.104
		4	1086.15	323.630
		5	1164.09	441.611
		6	1161.15	403.751
		7	1096.24	407.222
		8	1126.42	430.792
		9	1079.97	347.055
		10	1076.46	424.621
	ST	1	970.06	317.348
		2	749.89	188.954
		3	707.69	194.850
		4	723.22	206.009
		5	734.25	225.632
		6	749.12	272.860
		7	719.83	316.002
		8	753.05	275.283
		9	711.32	229.456
		10	685.88	190.851

Note: NA=NATO Alphabet Task UAS=UAS Task

Direct Test Data

DV	Training Condition	Training Block	*M*	*SD*
NA	MT	1	1835.72	463.828
		2	1730.01	320.444
		3	1714.28	312.687
		4	1696.36	202.627
		5	1787.80	436.671
		6	1772.12	208.412
		7	1732.70	288.797
		8	1698.21	208.568
		9	1775.42	276.092
		10	1661.38	226.946
	ST	1	1879.55	343.535
		2	1826.64	320.087
		3	1713.35	316.303
		4	1772.22	427.949
		5	1771.13	234.730
		6	1716.87	370.818
		7	1737.12	385.832
		8	1752.34	298.443
		9	1728.24	381.172
		10	1699.23	296.932
UAS	MT	1	1251.5316	302.31938
		2	1163.1918	236.72451
		3	1147.0857	245.53499
		4	1176.0736	266.64165
		5	1160.9717	298.13790
		6	1218.0281	354.38304
		7	1239.2563	390.63357
		8	1187.0398	258.84414
		9	1235.7290	400.36616
		10	1098.3153	287.24734
	ST	1	1451.7595	426.96914
		2	1381.5418	393.55544
		3	1252.1336	384.80577
		4	1297.6476	430.25030
		5	1286.2434	325.28958
		6	1293.8449	344.45878
		7	1265.2976	344.33122
		8	1241.0833	333.67075
		9	1241.5734	324.99741
		10	1180.4876	359.38470

Note: NA=NATO Alphabet Task UAS=UAS Task

Near Transfer Data

DV	Training Condition	Training Block	*M*	*SD*
NA	MT	1	2366.86	372.841
		2	2323.03	308.179
		3	2329.09	471.737
		4	2296.06	354.989
		5	2318.19	413.513
		6	2081.73	334.538
		7	2121.11	340.178
		8	2049.70	235.957
		9	2018.63	259.507
		10	2111.25	375.780
	ST	1	2543.78	442.614
		2	2292.77	425.877
		3	2336.79	378.429
		4	2274.78	266.105
		5	2285.38	323.618
		6	2090.04	389.795
		7	1991.19	225.659
		8	2118.41	307.036
		9	2142.83	276.596
		10	2091.00	307.942
ME	MT	1	1884.93	334.836
		2	1988.73	450.536
		3	1919.82	393.939
		4	1961.23	484.256
		5	1867.97	571.376
		6	1877.13	464.870
		7	1742.63	428.373
		8	1963.92	387.374
		9	1775.42	389.835
		10	1929.69	462.235
	ST	1	1650.60	414.902
		2	1718.32	463.060
		3	1667.79	425.454
		4	1643.88	365.512
		5	1578.21	469.923
		6	1734.51	397.866
		7	1611.63	354.721
		8	1673.68	427.397
		9	1738.29	395.479
		10	1617.35	429.607

Note: NA=NATO Alphabet Task ME=Military Equipment Task

Appendix B

Reaction Time Descriptive Statistics for Experiment 2

Training Data

DV	Training Condition	Training Block	*M*	*SD*
NA	MT	1	2025.28	414.905
		2	1904.36	723.936
		3	1809.15	514.233
		4	1946.49	414.316
		5	1909.48	424.591
		6	1921.01	496.264
		7	1828.75	415.935
		8	1707.67	285.971
		9	1591.62	589.012
		10	1738.74	427.926
	ST	1	1409.51	169.252
		2	1334.78	207.222
		3	1362.03	325.413
		4	1291.47	180.778
		5	1363.47	292.528
		6	1314.66	126.102
		7	1170.73	381.195
		8	1157.93	352.462
		9	1182.08	261.545
		10	1124.83	323.467
UAS	MT	1	1135.14	684.554
		2	1535.54	527.460
		3	1599.76	481.839
		4	1482.84	416.311
		5	1365.14	466.334
		6	1431.93	454.031
		7	1363.53	300.556
		8	1188.27	374.124
		9	1132.69	445.801
		10	1240.42	480.218
	ST	1	1000.94	274.775
		2	839.34	324.206
		3	798.05	305.628
		4	704.63	289.519
		5	768.70	327.206
		6	712.04	284.699
		7	714.08	337.771
		8	703.52	239.715
		9	717.79	373.562
		10	757.12	443.476

Note: NA=NATO Alphabet Task UAS=UAS Task

Direct Test Data

DV	Training Condition	Training Block	*M*	*SD*
NA	MT	1	1838.87	491.700
		2	1790.80	388.182
		3	1689.05	397.021
		4	1820.25	423.050
		5	1791.93	420.451
		6	1772.59	314.317
		7	1750.00	357.195
		8	1826.04	422.568
		9	1792.74	323.128
		10	1919.36	504.619
	ST	1	1914.36	500.128
		2	1564.10	408.120
		3	1589.05	371.412
		4	1764.26	408.698
		5	1896.62	409.017
		6	1853.58	348.116
		7	1862.90	436.039
		8	1872.59	505.022
		9	1892.12	466.739
		10	1740.79	266.413
UAS	MT	1	1361.9144	488.08653
		2	1334.2200	385.59478
		3	1316.9778	415.88972
		4	1326.3067	385.57997
		5	1324.2856	454.09476
		6	1323.6044	344.65799
		7	1261.4833	378.30083
		8	1370.9611	457.39329
		9	1346.9544	417.89375
		10	1463.3533	545.29890
	ST	1	1443.4511	272.07933
		2	1216.4378	458.01188
		3	1172.3844	498.97808
		4	1366.0956	501.74276
		5	1458.3844	533.93419
		6	1379.2067	360.70766
		7	1377.3189	380.91634
		8	1413.1178	393.68808
		9	1373.3911	285.95149
		10	1240.1700	244.00570

Note: NA=NATO Alphabet Task UAS=UAS Task

Near Transfer Data

DV	Training Condition	Training Block	*M*	*SD*
NA	MT	1	2526.21	556.967
		2	2369.35	525.056
		3	2404.06	545.822
		4	2287.55	464.749
		5	2435.82	587.608
		6	2381.17	537.702
		7	2276.85	418.612
		8	2421.94	536.895
		9	2349.57	497.883
		10	2318.35	522.140
	ST	1	2473.16	706.685
		2	2419.00	538.693
		3	2431.38	612.020
		4	2192.23	557.710
		5	2167.01	599.595
		6	2092.96	471.875
		7	2007.91	485.404
		8	1958.78	414.031
		9	2052.13	458.924
		10	2029.53	374.004
ME	MT	1	1819.81	379.299
		2	1898.90	474.782
		3	1777.73	454.762
		4	1795.20	551.028
		5	1793.34	546.019
		6	1782.20	492.163
		7	1771.16	495.246
		8	1728.52	375.048
		9	1715.88	453.132
		10	1630.91	371.497
	ST	1	2055.86	742.419
		2	1889.66	605.935
		3	1865.16	633.116
		4	1850.04	740.883
		5	1753.76	722.036
		6	1670.18	607.005
		7	1576.12	620.045
		8	1521.15	527.740
		9	1746.59	614.668
		10	1650.87	534.799

Note: NA=NATO Alphabet Task ME=Military Equipment Task